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NORTH CAROLINA: NATURAL NIDUS FOR ROCKY MOUNTAIN SPOTTED FEVER

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Introduction

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Most people would correctly guess that Rocky Mountain Spotted Fever (RMSF) originated somewhere in the Rocky Mountain Region of the American West. Even geographers, however, might be surprised to learn that the disease has long been insignificant in its region of origin, yet, is increasingly prevalent in the Southeast, particularly in North Carolina.

It is ironic that this spatially-concentrated, regionally-relevant, innately-geographic problem has received so little attention from geographers beyond Pyle's (1979) account. In a relatively recent study, Newhouse et al. (1986) analyzed the social and environmental factors affecting the occurrence of RMSF in Georgia from 1961-75. Among the ten variables selected to predict the occurrence of RMSF, the authors note that "the most important variables were those of climate and geography" (Newhouse et al., 1986). They also note that "of secondary, but still major importance, were those variables associated with humans and their environmental alterations" (Newhouse et al., 1986). Their well informed and conclusive study is typical of the literature on RMSF, which is dominated by contributions from medical and public health officials, whose findings often rely on a superficial understanding of the geographic variables involved. Moreover, cutting-edge spatial analytical techniques are rarely employed.

Most people might me surprised to learn that Rocky Mountain Spotted Fever is increasingly prevalent in North Carolina

This paper examines RMSF from a geographic perspective. Following a brief history, we explain the cultural ecology of the disease, describe its prevalence in North Carolina, and identify potential points for intervention. We conclude by calling for greater efforts by geographers to better understand and even predict the occurrence of this spatially-concentrated and regionally-relevant problem.

Historical Background

RMSF was first described in eastern Idaho during the late 19th century (Raoult and Walker, 1990), although the disease probably existed among Indians in the valleys of the Rocky Mountains long before the arrival of white settlers (Stuart-Harris, 1967). The first published report of the malady was made in 1896 by Major Marshall Wood, a US Army physician stationed in Boise, Idaho (Harden, 1990).

Incidence throughout the Bitterroot Valley of western Montana prompted subsequent research before the turn of the century. By 1906, Dr. Howard Ricketts established the infectious nature of the illness and demonstrated the role of ticks as vectors in western Montana (Raoult and Walker, 1990). Shortly thereafter, his associates identified the specific disease-causing agent.

Prior to the 1920s, RMSF was virtually unknown outside of the Rocky Mountain States. The first case east of the Mississippi River was reported in Indiana in 1925 (Horsfall, 1949), and by the 1930s, the disease had become well established in the East, accounting for almost half of the reported cases (Riley, 1977). By the mid 1970s, the disease had become prevalent in the East, Southeast, and South Central US, accounting for almost 97 percent of all reported cases (Riley, 1977). This trend continued through the mid 1980s, with highest incidence rates consistently occurring in North Carolina (Figure 1).

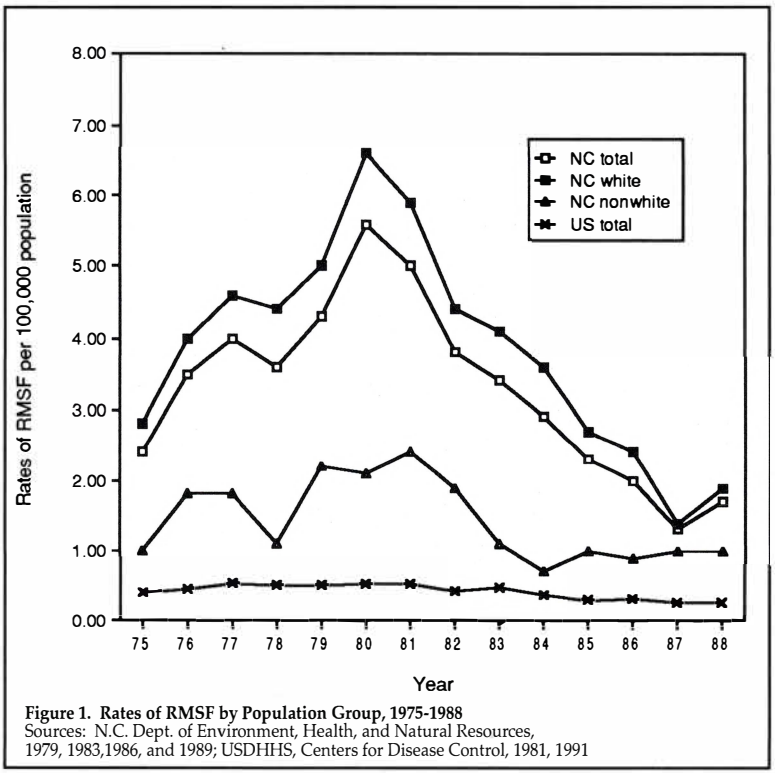


Figure 1. Rates of RMSF by Population Group, 1975-1988
Sources: N.C. Dept. of Environment, Health, and Natural Resources, 1979, 1983,1986, and 1989; USDHHS, Centers for Disease Control, 1981, 1991

Although the causative organism, its vector, and route of transmission have been known for more than 85 years, RMSF remains the most prevalent rickettsial disease in the US, and one of the country's most severe of all infectious diseases (Weber and Walker, 1991). Currently, the disease is most prevalent in a core region

extending from the Piedmont of the Southeast, westward through the Mid-South and into Oklahoma (Figure 2). Based on reported figures, North Carolina far exceeds any other state in the number of cases annually.

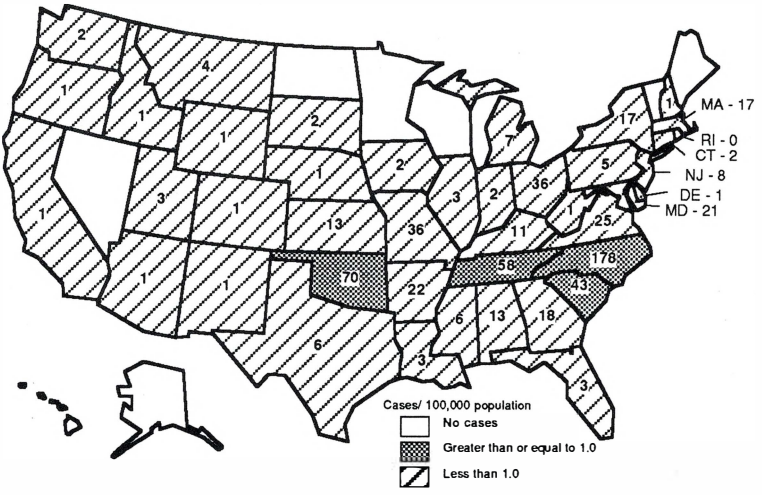
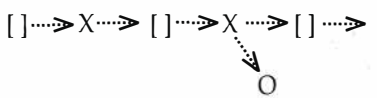


Figure 2. Reported Cases and Incidence Rates of RMSF in U.S., 1990
Source: USDHHS, Centers for Disease Control, 1991

A Cultural Ecology of Rocky Mountain Spotted Fever

RMSF is caused by one of a group of organisms known as rickettsiae. These microorganisms are structurally related to bacteria, but in other characteristics they resemble viruses. The specific agent of RMSF is Rickettsia rickettsii (named in honor of Dr. Ricketts) and is transmitted by the bite of an infective tick. Unlike most arthropod-borne pathogens, the causative organism can be passed directly from one generation of ticks to the next (Riley, 1977). RMSF is a vectored "zoonosis" (i.e., a disease which primarily infects animals), and is communicable between vertebrate animals and humans, and between various species of animals.

The chain of disease transmission for RMSF is simplified as follows:



where: [ ] = animal host
X = vector
O = human
····> = cycle of transmission

The animal host ranges from a variety of rodents to dogs and large hoofed mammals. Among the more common rodent hosts are the meadow and pine vole, chipmunk, white-footed mouse, cotton rat, cottontail rabbit, opposum, and snowshoe hare (Burgdorfer, 1980). The vector is the hard shell (ixodid) tick, which also serves as the main reservoir (Raoult and Walker, 1990). People serve as "dead end" hosts in the transmission chain, in that they cannot transmit the agent to a vector for transmission to another host (Meade et al., 1988).

A more detailed portrayal of the disease cycle is provided by Figure 3. A complete cycle is approximately two years, based on the lifespan of the tick. One can begin to analyze the cycle at the point where an infected, female adult tick has completed her third of three "blood meals" from a large wild or domestic animal, such as a horse, cow, deer, goat, or dog. The tick then falls to the ground and lays up to 10,000 eggs (many of which are transovarially infected) and subsequently dies. Within about 36 days the eggs hatch into larvae. These "seed ticks" subsequently cling to vegetation during their quest for small rodent hosts, in order to consume the first of three blood meals during their lives. After feeding for approximately one week, each larva falls back to the ground and enters the nymph phase of its life cycle. After finding another small animal host, each nymph consumes the

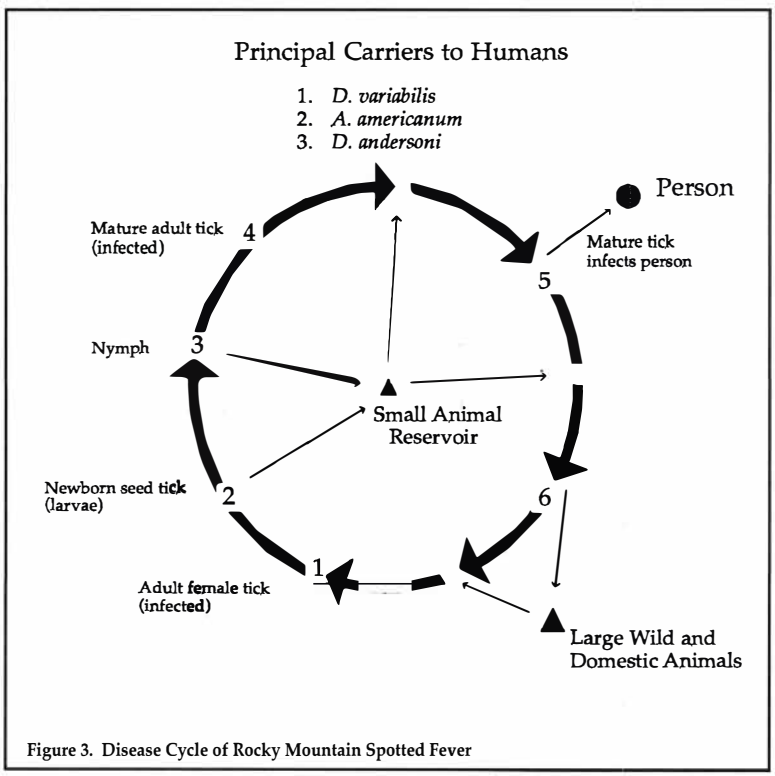


Figure 3. Disease Cycle of Rocky Mountain Spotted Fever

second of its blood meals, after which it falls to the ground and develops into an adult tick. At this point in time, the infected ticks are capable of transmitting the infectious agent of RMSF to a human host.

The infection cycle in humans commences when R. rickettsia is inoculated into the skin from the saliva of a feeding tick, a process which can only occur after several hours of feeding (Weber and Walker, 1991). After being bitten by the infected tick, an incubation period ensues for a period of 3-10 days. During this time, the rickettsiae produce an inflammation of the inner linings of the blood vessels (USDHHS, 1985). The inflammation eventually becomes visible in the form of a rash, comprised of many red spots under the skin and often concentrated around the wrists and ankles (although it later spreads to the trunk and limbs). The rash often appears on the palms of the hands and the soles of the feet, a symptom that is unique to RMSF and consequently provides a definitive diagnostic sign (Harden, 1990). Unfortunately, many people never become "clinical" (i.e., they never develop symptoms).

It normally takes six hours of feeding before R. rikettsia is inoculated into the skin through the saliva of the feeding tick

The rash may be preceded by several days of chills, high fever, headache, and bone pain (USDHHS, 1985). Other symptoms may include spinal and muscle stiffness, nausea, loss of appetite, and vomiting. Fever may range from 104° to 107° F, and if left untreated, may persist for several weeks, adversely affecting the central nervous system and resulting in delirium, convulsions or coma by the end of the first week (Blank and Rake, 1955). Critical circulatory and pulmonary complications can occur by the end of the second week (USDHHS, 1985). From the portal of entry in the skin, rickettsiae spread via lymphatics and the bloodstream to all body organs, including the heart, liver, kidneys, lungs, pancreas, gastrointestinal tract and the brain (Weber and Walker, 1991).

In worst-case scenarios, death can result from toxemia, vasomotor weakness, shock, renal failure, or respiratory or cardiac arrest (McDonald et al, 1987). In the US, case mortality has significantly declined, in part due to increased public awareness and early recognition of symptoms, but also because of the introduction of antibiotic treatments in the early 1950s. Whereas mortality resulted from 73 percent of the cases between 1895-1902 (Harden, 1990), by 1983 the case fatality rate of people who received antibiotic treatment had been reduced to 4 percent (McDonald et al., 1987).

As one might expect, neither incidence nor case fatality rates are uniform across the US population. Rates vary by age, sex, and race. Generally, the highest incidence of disease occurs in persons younger than 20 years of age (primarily 5-9 year olds), with the largest occurence among white males (USDHHS, 1981; CDC, 1991). Mortality rates are highest among persons age 40 and older, particularly among

black males (USDHHS, 1981; CDC, 1991). The former trend may be related to increased suburbanization and exposure to ticks within wooded recreational areas, and/or a close association with exposed household pets, specifically dogs (Pyle, 1979; Newhouse et al., 1986). We hypothesize that the latter trend may be attributed to the difficulty in detecting a rash during the early stages of the disease, and/or more limited access to health care. It must be emphasized, however, that the data upon which the above generalizations are based are far from being complete. Since the majority of people infected never develop symptoms, the above statistics are based only on clinical reports.

Inadequate reporting may contribute to the uneven rate of incidence among white and non-white populations. Data for North Carolina from 1975 to 1988 reveal the persistent pattern of higher incidence rates among the state's white population (review Figure 1). The researchers hypothesize that 1) the "activity space" of white residents is more apt to intrude into the "natural nidus" (i.e., the microscale region comprised of a living community among whose members a disease agent continually circulates, and the habitat required to maintain the disease (Meade et al, 1988)) of RMSF, and 2) more limited access to health care may result in underreporting the incidence among non-whites. Closer examinations of recreational and leisure location preferences, residential location, and access to health care for whites versus non-whites could yield greater insight into the causes of these trends.

Biocenose

RMSF exists in nature, independent of human activity. The disease agent occupies a specific environment (referred to as its "biocenose") that enables it to coexist with its vector (which in the case of RMSF, also forms the reservoir) and hosts. Since the three factors of agent, vector and host coincide independent of human activity, "silent zones" (conceptualized by May (1958) as places where the disease thrives, yet it remains undetected because people are not present) occur throughout the hemisphere, making it historically difficult to precisely distinguish between the potential and actual nidus of the disease.

The causative organism of RMSF is only found in the western hemisphere, and prevails throughout North, South, and Central America (Harden, 1990). The disease is transmitted by a variety of different ticks that flourish in specific ecological niches throughout the hemisphere.

In the US, the two primary vectors are the wood tick (Dermacentor andersoni) in the Rocky Mountain and western states, and the dog tick (Dermacentor variabilis) in the eastern and southern states. The wood tick is the "original" vector identified by Ricketts in 1906 and continues to be found on many species of animals throughout the Rockies. Of much greater concern, however, is the dog tick, so named because it primarily infests dogs and other domestic animals. More importantly, the

dog tick is the principal vector in the Piedmont region of the Southeast, which has accounted for a disproportionate number of cases of RMSF over the past fifty years.

Data from multiple sources show that the "tick season" runs from early spring through summer (USDHHS, 1979; USDHHS, 1984; USDHHS, 1987; Raoult and Walker, 1990; Riley 1977). Despite the significant decline in the number of reported cases between 1980 and 1990, the pattern of monthly onset remains virtually unchanged (Figure 4). This seasonality of the incidence of RMSF reflects the seasonal

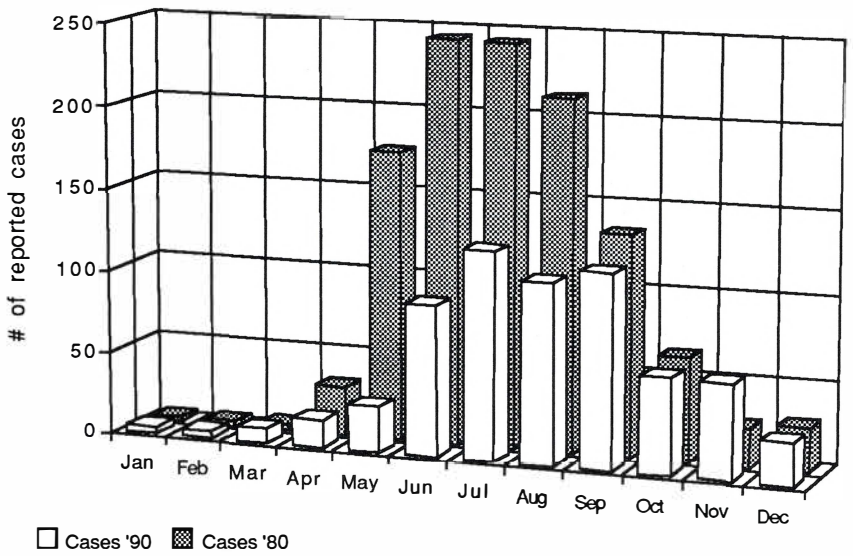


Figure 4. Monthly Onset of RMSF, 1980 and 1990
Sources: USDHHS, Centers for Disease Control, 1981 and 1991

activity of adult ticks (since immature forms seldom transmit the disease to humans), which actively feed during the spring and summer (Riley, 1977).

Generally, ticks are found in heavily wooded, mountainous, or sagebrush areas of the US (USDHHS, 1987; USDHHS, 1985; USDHHS, 1984). Open or patchy woodland, brushy areas, and abandoned overgrown fields and pastures also provide ideal habitat for wood and dog ticks alike (Riley, 1977; Pyle, 1979). Sonenshine et al. (1972) concluded that the range of the dog tick coincides with that of the eastern deciduous biome, and is largely confined within an area receiving at least 102 centimeters of average annual rainfall and experiencing a daily relative humidity of 70 percent or greater. The range is delimited by a latitudinal line beyond

which temperatures may dip below O° C for extended periods of time to the north, and a longitudinal line of precipitation stress to the west, while including all of the southeastern mixed forest (Sonenshine et al., 1966; 1972). McEnroe and McEnroe (1973) also recognized the importance of the climatic variables of temperature and

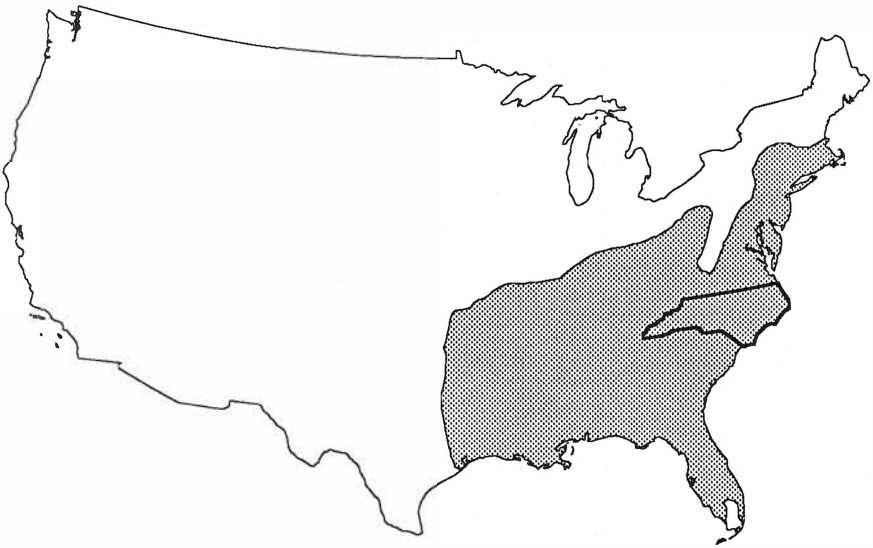


Figure 5. Ideal Environmental Conditions for the Dog Tick

relative humidity, noting that temperature and humidity significantly affect the questing behavior of ticks. More specifically, they concluded that the optimum questing temperature was 20° C, with an upper threshold of 40° C and a lower limit of 5° C (McEnroe and McEnroe, 1973). As relative humidity declines, ticks retreat to the soil surface in search of increased moisture, and return to questing only once the minimum required saturation level (about 60 percent) returns (McEnroe and McEnroe, 1973).

Humans are incidental hosts, yet they may enhance or reduce the spread of the disease. Exposure through interaction with pets, for example, should not be underestimated.

The environmental factors and conditions identified above by Sonenshine and others enable one to geographically delimit the territory of the dog tick (Figure 5). Unfortunately for its residents, North Carolina provides an ideal habitat, and hence the potential for RMSF. Pavlovsky (1966) referred to this "natural focus" of a disease as its "natural nidus," within which the infection is maintained among wild animals and arthropod vectors. As explained by Meade et al. (1988), scientists can subsequently use the landscape to identify disease hazards once they understand the specific environmental conditions required for a particu-

lar disease. It is significant to note, however, that human behavior can significantly alter disease cycles (such as RMSF) that ordinarily exist independently in nature (Meade, 1977).

The Impact of Cultural Behavior

Because RMSF has a natural nidus, by definition, humans cannot "create" the disease. People are merely incidental hosts. Nevertheless, through various beliefs and activities, humans may enhance or reduce the spread of the disease, become exposed to it, or establish a variety of cultural buffers as means of controlling the disease cycle.

Pyle (1979) notes that there are differing theories which explain the shift in geographic foci of the disease from the Rocky Mountain region to the eastern US. It is doubtful that the causative organism diffused from the original source region in the West to a new core in the East. Better disease control and a sparse, yet stable population after the initial outbreaks of RMSF may account for the decline in incidence of the disease in the West. In the East, it appears that human activities such as migration, changing settlement patterns, suburbanization, and increased outdoor recreation in wooded areas have resulted in significant intrusion into "silent zones," prompting a dramatic increase in exposure to ticks. Other explanatory factors in the East might include greater awareness and improved reporting, insofar as the latter contributes to better statistics. These explanations are consistent with Roundy's (1980) contention that humans, through cultural or individual behavior, play roles in the success or mitigation of communicable disease agent life cycles. Roundy noted that people, through environmental foci, present themselves at sites where a disease agent can be transmitted to them. He specifically highlighted the influence of human-induced vegetational changes on disease patterns (Roundy, 1980).

Burgdorfer (1977) explained that RMSF was an "occupational disease among people settling in enzootic areas" in the West, and once the land was cleared and cultivated, incidence of RMSF declined as a function of decreased tick infestation. In the East, the highest incidence rates occurred among children and women because the dog tick primarily infected household pets, with which they constantly maintained contact (Burgdorfer, 1977). When populations began to shift into the natural foci of RMSF via suburbanization or recreational activities within previously cleared agricultural lands, alarming rates of incidence ensued. Raoult and Walker (1990) reached the same conclusion as Burgdorfer, lending support to the contention that current incidence patterns are largely related to cultural behavior and intrusions into the natural nidus of the dog tick by both humans and their pets. Exposure through interaction with pets should not be underestimated, since recent surveys have found that sharing homes with pets is a way of life for more than 60 percent of Americans (Folkenberg, 1990).

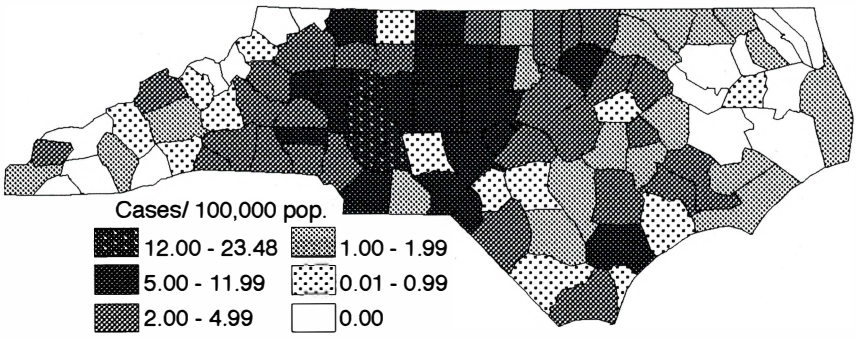


Figure 6a. Seven Year Average Incidence Rates of RMSF in NC, 1975-81
Sources: N.C. Dept. of Environment, Health, and Natural Resources, 1989;
N.C. Dept. of Human Resources, 1980, 1985, 1989

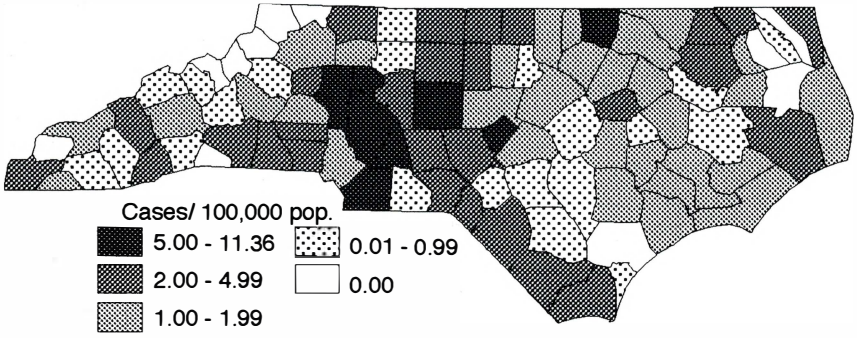


Figure 6b. Seven Year Average Incidence rates of RMSF in NC, 1982-1988
Sources: N.C. Dept. of Environment, Health, and Natural Resources, 1989;
N.C. Dept. of Human Resources, 1980, 1985, 1989

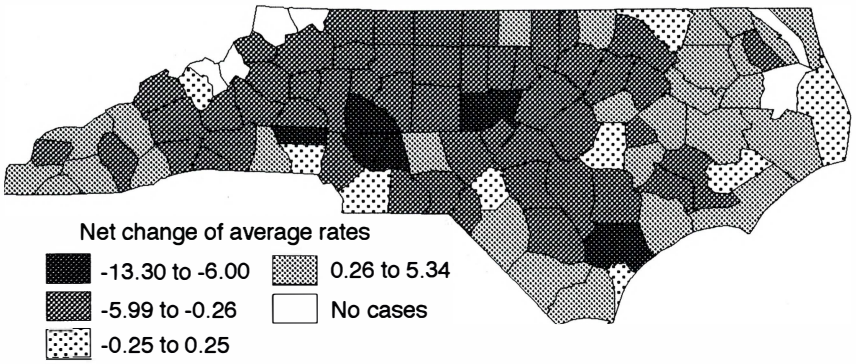


Figure 6c. Net Change in Average Incidence Rates of RMSF in NC; Net Change = (1982-1988 rate) - (1975-1981 rate)
Sources: N.C. Dept. of Environment, Health, and Natural Resources, 1989;
N.C. Dept. of Human Resources, 1980, 1985, 1989

A closer examination of the incidence rates in North Carolina reveals the dynamic nature of the pattern (Figures 6a, 6b and 6c). Figures 6a and 6b provide a comparison of average incidence rates per 100,000 population for two seven-year periods, 1975-1981 and 1982-1988.

Figure 6c indicates the resulting net changes in average incidence rates for each county in North Carolina. One can make the following inferences from these comparative maps: 1) incidence rates remain significantly higher in North Carolina than in other states despite a significant decline in the state's incidence rate in recent years; 2) highest incidence rates within North Carolina remain concentrated in the Piedmont section of the state, despite significant declines in incidence rates within this region; and 3) although still not as significant as in the Piedmont, increased incidence rates have occurred in both the Coastal Plain and the Mountain regions during recent years. Further research and resolution at a finer spatial scale are required to determine whether the high rates of incidence within the Piedmont region can be attributed to physical geographical factors or more widespread changes in population and land-use.

Intervention Points

A strategy for effectively intervening in the disease cycle of RMSF includes alternatives selected from the following general areas: eradication, behavior modification, medical treatment, and preventative measures. These are not new alternatives; rather, they represent the general options from which culture groups have historically selected an appropriate means to combat a disease.

Eradication would be geared towards eliminating tick-infested areas, best accomplished through the use of chemical pesticides. This alternative would be extremely expensive (if at all possible) and would subject people and the environment to the harmful side effects of pesticides. Perhaps more problematic would be the effort to target actual carriers of the disease. As Roueche (1988) noted, the vector tick is ubiquitous in range, and even in the most heavily infested areas, only 5 percent of the vector ticks are carriers.

The most effective prevention measure for avoiding Rocky Mountain Spotted Fever is to physically check one's body and to promptly and carefully remove any discovered

Behavior modification would focus on the choice of recreational activities and the location of those activities, as well as owning and caring for pets (especially dogs). Partial solutions to the problem of avoiding tick-infested areas might be to forego certain outdoor recreational activities in wooded areas, such as hiking, camping, hunting, or fishing. This is not a realistic alternative nor are people likely to relinquish their pets or restrict the latter from going outside the house. Exposure can be minimized, however, by understanding a basic aspect of tick behavior. As Houle (1991) concluded, ticks climb vegetation early in the day to engage in "questing" (i.e., search behavior to find a suitable

blood meal) for several hours. As the mid-day sun becomes extremely hot, the ticks retreat back to the ground and take refuge in cooler, moist areas. Thus, individuals can minimize their exposure and that of their pets by engaging in some activities later in the day.

Intervention via medical treatment is based on the use of antibiotics once the disease is diagnosed. This intervention strategy has proved extremely effective since the 1950s, especially when symptoms are identified early in the case. Antibiotics do not, of course, prevent people from contracting the disease (although they probably do decrease the number of "reported cases"); they merely provide a means of combatting the disease once a person becomes infected.

Preventative measures include a variety of means to help avoid contact with infected ticks. Although vaccines are common preventative measures, a commercially available vaccine does not exist for RMSF. Other preventative measures include wearing protective clothing (such as long trousers, long sleeve shirts, boots, and hats), using insect repellent, and purchasing "tick collars" for household pets. Each of these options however has its drawbacks. Protective clothing might not be practical during the hot, humid spring and summer "tick season" throughout the Southeast. Insect repellent is not always available each time one ventures into a tick-infested area (even if one could recognize such areas), nor is it convenient to continuously apply it, especially if one lives in a rural area. Tick collars are designed to prevent infected ticks from being brought into the house or yard and subsequently falling off and establishing a foci from which infected ticks may eventually evolve and infect the residents. Although tick collars are widely sold for household pets, they are rarely 100% effective, they fall off at inopportune times, and although they afford some protection to the pet, they do little to safeguard the owner.

We argue that the tools and techniques of the geographer are well suited to integrate the complex combinations of physical and human factors which account for the prevalence of this disease

The most effective preventative measure is to physically check one's body for ticks and to promptly and carefully remove ticks that are discovered. Because ticks usually require up to six hours of feeding before they can transmitt R. rickettsia into the human body, checking one's body two or three times a day can enhance detection and avoid infection. Using the "buddy system" is especially important to helping children avoid infection.

Conclusion

Despite a variety of options for intervening into the disease cycle, RMSF remains an important infectious disease because of its prevalence, the difficulty in correctly diagnosing the illness in a timely manner, and the potentially fatal outcome (Weber and Walker, 1991). Moreover, because the ticks themselves can act as the reservoir (infection can be transmitted transovarially from the adult female tick

to her eggs) and can survive for long periods of time (over a year) without feeding, the possibility of eradicating the disease appears remote.

It has been established that North Carolina provides an ideal environmental habitat for the dog tick (Dermacentor variabilis). Given the rapidly changing cultural landscape of the Southeast and the Mid-South, especially in North Carolina, it appears that humans throughout the region will continue to play the role of incidental hosts in the foreseeable future. Consequently, public awareness programs should be appropriately designed to help residents and travellers recognize the natural nidus of RMSF, recognize its early symptoms, and understand various intervention options in order to combat (or hopefully avoid) the disease.

A major purpose of this paper is to provide a stimulus for more geographic inquiry on the topic of RMSF in North Carolina. Geographers can make a significant contribution in defining the natural nidus of RMSF within the Southeastern US and predicting the occurrence of the disease through the use of Geographic Information Systems (GIS).

We recognize that the problem of RMSF has two components: 1) a physical geographical factor, which defines the natural nidus of the disease; and 2) a human geographical factor, which accounts for how and where people come into contact with infected ticks and subsequently contract RMSF. GIS can be employed to generate and integrate layers of both physical and human information. The physical variables might include: temperature, relative humidity, soil temperatures, vegetative cover, precipitation, and frost-free days. Human variables could incorporate changing land use patterns such as suburbanization, farm land abandonment, and recreational use of wooded and forested areas. These combinations of variables could be overlayed with data on RMSF, which is currently available at the county level from the Centers for Disease Control.

The brief discussion above is only one example of how a geographic perspective may enhance better understanding of this problem. We argue that the tools and techniques of the geographer are well suited to integrate the complex combination of physical and human factors which account for the prevalence of RMSF in the Southeastern US, and particularly in North Carolina.

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